

EP 225.3  
Department of Physics and Engineering Physics  
University of Saskatchewan  
Final Examination

Instructor: A.V. Koustov  
Time: 2:00 pm – 5:00 pm

April 16, 2005

**Notes:**      **Candidates are to answer all 10 questions**  
                 **All questions have the same value**  
                 **This is a closed book exam**

1.      An object is placed 5 cm from the front surface of a thick biconcave lens with the radius of the surfaces of 10 cm. The lens is made of glass with  $n=1.5$ , and it is 3 cm thick. Using the thick lens approach calculate (i) the image location with respect to the object (ii) the size of the image if the object is 1 cm tall and (iii) determine whether the image is real or virtual, upright or inverted (justify your answers). In this question, how can one judge experimentally whether the image is real or virtual? ✓

2.      A telescope is used to view an object on the Moon. It is focused to give a final image at the near point of a normal eye. Show that the angular magnification of the telescope is  $-f_0(1/f_E + 1/25)$ , where  $f_0$  and  $f_E$  are the focal lengths (measured in cm) of the objective and eyepiece lenses, respectively. ✗

3.      An achromatic system made of two thin lenses has total power of 7.5 D. One of the lenses has focal length of  $f = +10$  cm. (a) What is the focal length of the second lens? ✓  
(b) What is the separation between the lenses?

4.      (a) Show that the ratio of two successive maxima in the displacement of a damped harmonic oscillator is constant. ✓

✗ (b) An alternating voltage with amplitude  $V_0$  is applied across a LCR series circuit. Show that the voltage at current resonance across the inductance is  $QV_0$ , where  $Q$  is the quality factor of the circuit. ✗

5.      (a) In wave mechanics the dispersion relation for an electron of velocity  $v = \hbar k / m$  is given by  $\omega^2 / c^2 = k^2 + m^2 c^2 / \hbar^2$ , where  $c$  is the velocity of light,  $m$  is the electron mass (considered constant at a given velocity),  $\hbar = h / 2\pi$  and  $h$  is the Planck's constant. Show that the product of the group and phase velocities is  $c^2$ . ✓

(b) Explain the concepts of group and phase velocities.

6. (a) A submarine produces a noise of intensity  $10^{-4} \text{ W/m}^2$  at a frequency of 100 Hz. Would someone be able to detect the sound by simply sitting on a boat and hearing the noise? Assume that the sound incidents normally on the air-water boundary and remember that the threshold of hearing for humans is  $10^{-12} \text{ W/m}^2$ . In addition compute:

- i) The speed of the wave in air and water?
- ii) The wavelength of the wave in both media?
- iii) The displacement in the wave while it is in the air?
- iv) The pressure in the wave in the air and water?
- v) Express in decibels the ratio of the intensity of the transmitted wave in water to that of the incident wave in air.
- vi) Is there a phase change of the transmitted wave? Explain your answer.

(b) One source has loudnesses of 50 dB. What should be the loudness of another source in dB so that the two sources together would provide a loudness of 55 dB.

7. Monochromatic light in the visible part of the spectrum is incident normally on a thin film of oil ( $n=1.30$ ) that covers a glass plate. The thickness of the oil film is 400 nm. An interference pattern is viewed in the reflected light. Determine two wavelengths for which one would see a complete destructive interference in two sequential orders (assume that  $n_{\text{oil}} < n_{\text{glass}}$ ).

8. (a) Show that maxima in the diffraction pattern of a single slit can be derived from the equation  $\tan \beta = \beta$ , where  $\beta = \pi a \sin \theta / \lambda$ ,  $a$  is the width of the slit.

(b) What is a zone plate and for what purpose can one use it?

9. (a) A mercury light source radiates, among others, a blue line of 440 nm and a green line of 550 nm. If these two lines are to have an angular separation of at least  $7^\circ$  and if the grating available has 500 lines/mm, in which order must the grating be used?

(b) If you are to use this grating to resolve a doublet around green line with separation in wavelength of 0.55 nm, how many rulings should be used (illuminated) to resolve the doublet in the fourth order?

10. (a) Three polarizing filters are stacked, with the polarizing axes of the second and third at  $45^\circ$  and  $90^\circ$ , respectively, with that of first. If unpolarized light of intensity  $I_0$  is incident on the stack, find its intensity and state of polarization after each filter.

(b) Explain the meaning of the term "optically active material".

Some data: Atmospheric pressure =  $10^5 \text{ N/m}^2$ . Bulk modulus of water =  $2.1 \times 10^9 \text{ N/m}^2$ . Densities of air and water are  $1.29 \text{ kg/m}^3$  and  $10^3 \text{ kg/m}^3$ , respectively. The ratio of specific heats = 1.4.